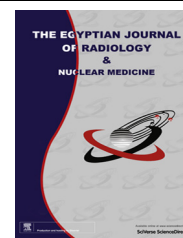




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**ORIGINAL ARTICLE**

# Ultrasonographic and clinical study of post-stroke painful hemiplegic shoulder



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**KEYWORDS**

Ultrasound;  
 Stroke;  
 Pain;  
 Shoulder

**Abstract** *Aim of the work:* To describe the structural abnormalities of the painful hemiplegic shoulder (PHS) by ultrasound (U/S) and their relationship with some clinical variables.

*Materials and methods:* Eighty consecutive patients with post-stroke PHS were subjected to both clinical assessment and ultrasonographic examination of both shoulders. Ultrasonographic imaging data were classified into five grades.

*Results:* The biceps tendon sheath effusion (51.25%) and the SA–SD bursitis (43.75%) were the most frequent abnormalities in the affected painful shoulder. No significant relationship ( $P = 0.114$ ) was found between the U/S grades of the painful hemiplegic shoulder and the Brunnstrom motor recovery stages. Ultrasonographic grades of the unaffected shoulder were significantly correlated with the stroke duration ( $P < 0.001$ ), the Brief Pain Inventory score ( $P < 0.05$ ), shoulder pain duration ( $P < 0.001$ ), and degree of spasticity ( $P < 0.001$ ).

*Conclusion:* Ultrasonography is an essential method in evaluation of post-stroke PHS. However, the U/S grades were not correlated with the stages of motor recovery. Avoiding overuse of the unaffected shoulder will be helpful for prevention of shoulder injuries following hemiplegic stroke.

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**1. Introduction**

Stroke is a medical emergency that can cause permanent neurological damage (1). Pain in the hemiplegic shoulder, which is one of the most common and distressing complications that patients may experience after stroke, has an incidence that ranges widely from 5% to 84% (2). The early onset of the painful hemiplegic shoulder (PHS) may hamper the rehabilitation process because patients avoid painful shoulder movement and withdraw from active rehabilitation, thus reducing the effectiveness of any motor restoration technique (2,3). The exact etiology of post-stroke shoulder pain remains unknown (4) and, most commonly many factors were involved (5).

*Abbreviations:* PHS, painful hemiplegic shoulder; U/S, ultrasound; SA–SD, subacromial–subdeltoid; BPI, Brief Pain Inventory; ROM, range of motion; RS, recovery stage

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Epidemiological and radiological studies, previously performed to identify the possible causes of PHS, have described neurological abnormalities including thalamic pain (6), shoulder muscle spasticity or flaccidity (7), and sympathetic dystrophy (8) as well as orthopedic abnormalities including impingement, rotator cuff tears, supraspinatus tendinosis, subacromial-subdeltoid bursal effusion, tendon sheath effusion of biceps long head and adhesive capsulitis (9,10). The PHS may interfere with functional improvement, the patient quality of life, and it may impede the process of rehabilitation (11).

Radiological methods are the most appropriate tools in the evaluation of shoulder pain, particularly when examining bony structures and joint subluxation is suspected. However, these methods cannot be used to examine soft tissue lesions (11). The primary noninvasive methods to diagnose shoulder pain and rotator cuff abnormalities are sonography and magnetic resonance imaging (MRI). However, it is difficult to perform shoulder MRI or MR arthrography in stroke patients with hemiplegia because of limited and intolerable positioning of the patients. Although there are some limitations in the usual dynamic examination of such patients, sonography is a noninvasive, widely available, and inexpensive imaging technique that can be used for the soft-tissue assessment. It combines direct multiplanar structural evaluation with dynamic investigation of movement, thereby providing both anatomic and functional elements to the assessment (12). Furthermore, high frequency ultrasonography established its role in the demonstration of different pathologies of the shoulder girdle complex that is difficult to identify by clinical examination (5).

The aim of this work was to describe the structural abnormalities of both the painful hemiplegic shoulder and the contralateral unaffected shoulder by ultrasound (U/S), in post-stroke patients. Additionally, we aimed to study the relationship of the U/S imaging grades of the painful hemiplegic shoulder with some clinical variables and the Brunnstrom motor recovery stages.

## 2. Patients and methods

This study was performed in the period between January, 2013 and October, 2013 on both shoulders (the painful hemiplegic shoulder and the contralateral unaffected shoulder) of 80 consecutive patients with hemiplegic shoulder pain; their ages ranged from 35–75 years (mean  $62.29 \pm 8.93$  years), referred from the Neurology department of our institution. The study included patients with first flare of shoulder pain within 1 year after 1st attack of stroke which resulted in hemiplegia and who had not experienced shoulder pain in both shoulders in the 6 months before the stroke. Exclusion criteria included history of previous shoulder injuries or surgery, history of previous steroid injection in the affected shoulder, neuromuscular disorders associated with shoulder weakness and/or pain (e.g., cervical disk disease), markedly limited range of motion so far as to hinder ultrasonographic evaluation, and severe cognitive impairment that impeded communication. The diagnosis of stroke had been made in all patients on the basis of patient history and clinical examination that was confirmed by the data of either CT or MRI. All patients were subjected to both clinical assessment and ultrasonographic examination of both shoulders. A written consent was obtained from all the

patients or their caregivers. The local institutional ethics board approval for this study was also obtained.

### 2.1. I-clinical assessment

Different clinical variables in eligible patients were evaluated. These variables included age, sex, handedness, type of stroke, duration of stroke, severity of hemiplegic shoulder pain, duration of shoulder pain, range of motion in the shoulder joints, degree of spasticity in the hemiplegic upper limb, composite muscle power score, and the level of functional activity (motor recovery after stroke).

The severity of pain in the PHS was quantified with the Brief Pain Inventory (BPI). The patients were asked to rate their shoulder pain in the last 7 days on a numeric ratio scale from 0 to 10 points, where “0” indicates no pain and “10” indicates pain as worse as the patient can tolerate (13,14). Range of motion (ROM) in both shoulders was examined in abduction, forward flexion, external rotation, internal rotation, adduction and extension. Limited ROM was present when the patient was not able to perform full ROM in either one of these directions. Spasticity was evaluated by using the 5-point Ashworth scale. The presence of shoulder spasticity was defined as an Ashworth scale score of  $\geq 1$  (15). The composite muscle power scoring was done according to the Medical Research Council (MRC) scoring system. This system grades the patient effort on muscle power examination on a scale of 0–5; where “0” indicates no movement observed and “5” indicates that the muscle contracts normally against full resistance (16).

The level of functional activity and motor recovery of the affected hemiplegic upper limb was assessed by the Brunnstrom staging. The lowest stage; flaccid stage with no voluntary movement (flaccid limb) is stage 1, and the highest stage; isolated joint movement and no longer spasticity, allowing near-normal movement and coordination, is stage 6 (17,18). We abbreviated the 6 Brunnstrom stages into 3 stages by combining two adjacent stages (stages 1–2, 3–4, and 5–6) according to the similarity of the effect of hemiplegic shoulder movement, so the patients were classified into 3 groups: the first, second and third recovery stages (RS1, RS2 and RS3, respectively).

### 2.2. II-ultrasonography

Ultrasonographic examination was done by radiologist who has an experience in musculoskeletal sonography and unaware of the clinical details of the patients. Both shoulders in all patients were examined (the affected painful hemiplegic shoulder and the contralateral unaffected shoulder). Ultrasonographic examination was performed, using a linear array transducer of 12 MHz frequency connected to a real-time ultrasound machine (Biomedical P-K, Denmark) with optimized settings, for the assessment of the long head of biceps tendon, the rotator cuffs, and subacromial-subdeltoid bursa (SA–SD bursa) of both shoulders. Most of patients underwent shoulder sonography while seated on a wheelchair, using the usual scanning techniques as previously reported by Moosikasuwan et al. and Teefey et al. (19,20). However the usual techniques were difficult for hemiplegic patients because of limits in movements, so we examined the shoulder in position

similar to that used for the usual dynamic examination, by passive movement by an assistant as long as the patient can tolerate pain, muscles of both shoulders in all patients were examined in both transverse and longitudinal planes.

### 2.3. Imaging analysis

Ultrasonographic examination evaluated the presence or absence of tendinosis, presence or absence of rotator cuff tear, SA–SD bursal fluid or wall thickening, and abnormalities of long head of biceps tendon and effusion. Decisions regarding the imaging interpretations depended upon the data of the previously published studies.

Signs suggestive of partial thickness cuff tear included a heterogeneous tendon with hypoechoic areas (more than 3 mm) that did not reach both sides of the tendon or a large linear echogenic focus within the cuff substance (i.e., purely intrasubstance tear) and a hypoechoic defect that involved the articular or bursal surface (21–23).

Sonographic findings for full thickness rotator cuff tear included non-visualization or absence of cuff tissue, a full-thickness hypoechoic defect, visualization of the underlying hyaline cartilage and a heterogeneously hypoechoic cuff with bursal fluid (23,24). A heterogeneous tendon with an increase or more than 8 mm in tendon thickness was considered to indicate tendinosis (24). Tendon fluid was hypoechoic or anechoic, freely displaceable and compressible and did not exhibit any color Doppler signal (25). The SA–SD bursa was imaged as a hypoechoic line 1–2 mm thickness with variable amount of peribursal echogenic fat, located between the deltoid muscle and the supraspinatus and infraspinatus tendons, so we determined the established criterion for SA–SD bursitis to be a hypoechoic fluid-filled bursa more than 2 mm thickness (26).

To better define the relationship between ultrasonographic findings and different clinical variables, ultrasonographic imaging data were classified into five grades according to the ultrasonographic findings. This grading system has received support from previously published research (12,27,28). The sonographic grades were as follows: grade 1; normal or effusion of the long head of biceps tendon sheath, grade 2; tendinosis of the supraspinatus, grade 3; SA–SD bursitis, grade 4; partial-thickness tear of the rotator cuff, and grade 5; a full-thickness tear of the rotator cuff. If there were more than two abnormal ultrasonographic findings, the case was classified based on the most severe finding (12).

### 2.4. Statistical analysis

It was designed to compare the ultrasonographic grades between the affected painful hemiplegic shoulder and the contralateral unaffected shoulder, also to investigate the relationship between the ultrasonographic grades and different clinical variables in both the affected and unaffected shoulders, and also to detect the correlation between abnormal sonographic findings and the Brunnstrom stages of motor recovery. Data were expressed in number, percent, and mean  $\pm$  standard deviation (SD). Student's *t*-test and *chi*-square test and the analysis of variance (ANOVA) with Spearman's rho test were used for comparison and correlation of the data. The SPSS for Windows version 18.0 software package (SPSS Inc, Chicago,

IL) was used for statistical data analysis. *P*-value  $< 0.05$  was considered statistically significant.

## 3. Results

The age of the studied patients ranged from 35 to 75 years with a mean of  $62.29 \pm 8.93$  years. Most of them were males (56.25%), while 43.75% were females. Other clinical variables are shown in Table 1.

The U/S grade 1 was the most frequent U/S grade in both the affected (46.25%), and the unaffected (37.50%) shoulders. No significant correlation ( $P = 0.658$ ) was found in the U/S grades between the affected and unaffected shoulders, Table 2.

Abnormal U/S findings are more frequent in the painful hemiplegic shoulders (65/80; 81.25%) than the contralateral unaffected shoulders (38/80; 47.5%), where the biceps tendon sheath effusion (51.25%) and the SA–SD bursa (43.75%) were the most frequent abnormalities in the affected painful shoulder, Table 3. One abnormal sonographic finding was seen in 54 patients, two abnormal sonographic findings were seen in 21 patients and 3 abnormal sonographic findings were seen in 5 patients.

Table 4 shows that, no significant relationship ( $P = 0.114$ ) was found between the U/S grades of the affected painful hemiplegic shoulder and Brunnstrom motor recovery stages. Additionally, our results showed that, grade 3 (SA–SD bursitis) of abnormal sonographic findings was more frequent in patients of RS3 (46.15%) and RS1 (42.86%) groups. On the other hand, the most frequent abnormal sonographic finding among patients with RS2 was grade 1 U/S (biceps tendon effusion) as more than half of patients with RS2 (62.5%) had biceps tendon effusion by U/S examination.

**Table 1** Clinical variables of the studied patients ( $n = 80$ ).

Clinical variables		Statistics
Age (in years)	Range	35–75
	Mean $\pm$ SD	$62.29 \pm 8.93$
Sex	Female	35 (43.75%)
	Male	45 (56.25%)
Handedness	Right-handed	63 (78.75%)
	Left-handed	17 (21.25%)
Type of stroke	Ischemic	64 (80%)
	Hemorrhagic	16 (20%)
Duration of stroke (in days)	Range	15–183
	Mean $\pm$ SD	$61.91 \pm 30.4$
Duration of shoulder pain (in days)	Range	7–93
	Mean $\pm$ SD	$45.64 \pm 15.9$
BPI score	Range	1–9
	Mean $\pm$ SD	$4.68 \pm 2.45$
ROM in the affected shoulder	Full	31 (38.75%)
	Limited	49 (61.25%)
Degree of upper limb spasticity	Range	0–5
	Mean $\pm$ SD	$1.96 \pm 1.38$
Muscle power score of the affected shoulder	Range	0–5
	Mean $\pm$ SD	$2.38 \pm 1.3$
Brunnstrom recovery stage	RS1	35 (43.75%)
	RS2	32 (40.00%)
	RS3	13 (16.25%)

BPI: Brief Pain Inventory, ROM: range of motion, RS: recovery stage, SD: standard deviation.

**Table 2** Different U/S grades in the affected and unaffected shoulders in the studied patients ( $n = 80$ ).

U/S grades of affected shoulder	U/S grades of unaffected shoulder					
	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Total
Grade 1	15 (18.75)	5 (6.25)	6 (7.50)	7 (8.75)	4 (5.00)	37 (46.25)
Grade 2	3 (3.75)	0 (0.00)	2 (2.50)	0 (0.00)	0 (0.00)	5 (6.25)
Grade 3	12 (15.00)	9 (11.25)	1 (1.25)	5 (6.25)	4 (5.00)	31 (38.75)
Grade 4	0 (0.00)	4 (5.00)	0 (0.00)	0 (0.00)	0 (0.00)	4 (5.00)
Grade 5	0 (0.00)	0 (0.00)	1 (1.25)	1 (1.25)	1 (1.25)	3 (3.75)
Total	30 (37.50)	18 (22.50)	10 (12.50)	13 (16.25)	9 (11.25)	80 (100)
Spearman's rho	$r$ 0.050					
	$P$ -value 0.658					

**Table 3** Distribution of different US findings in the affected versus unaffected shoulders in the studied patients ( $n = 80$ ).

U/S findings	Affected hemiplegic shoulder		Unaffected shoulder		Chi-square	
	$N$	%	$N$	%	$\chi^2$	$P$ -value
Normal findings without biceps tendon sheath effusion	15	18.75	42	52.50	19.867	0.000*
Biceps tendon sheath effusion	41	51.25	22	27.50	9.452	0.002*
SA-SD bursa	35	43.75	19	23.75	7.156	0.007*
Tendinosis of SST	9	11.25	4	5.00	2.093	0.148
Partial-thickness tear of SST	8	10.00	3	3.75	2.441	0.118
Full-thickness tear of SST	3	3.75	0	0.00	4.216	0.040*

SA; subacromion, SD; subdeltoid, SST; supraspinatus tendon.

\* Significant ( $P < 0.05$ ).**Table 4** The relation between the U/S grades in affected hemiplegic shoulder and the motor recovery stage (Brunnstrom stages).

Brunnstrom stages	U/S grades of affected shoulder						Chi-square	
	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Total	$\chi^2$	$P$ -value
RS1	12 (15.0)	2 (2.50)	15 (18.75)	3 (3.75)	3 (3.75)	35 (43.75)	12.95	0.114
RS2	20 (25.0)	1 (1.25)	10 (12.50)	1 (1.25)	0 (0.00)	32 (40.00)		
RS3	5 (6.25)	2 (2.50)	6 (7.50)	0 (0.00)	0 (0.00)	13 (16.25)		

Note: numbers in parenthesis are percentages. RS: recovery stage.

**Table 5** Correlation between clinical variables and U/S grades of affected shoulders.

Clinical variable		U/S grades of affected shoulder						Spearman's rho	
		Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	$r$	$P$ -value	
Age in years	Mean $\pm$ SD	61.84 $\pm$ 9.74	60.60 $\pm$ 9.017	63.39 $\pm$ 8.41	60.00 $\pm$ 10.10	62.33 $\pm$ 5.13	0.006	0.955	
Duration of stroke in days	Mean $\pm$ SD	62.05 $\pm$ 30.67	39.40 $\pm$ 26.46	65.29 $\pm$ 30.29	43.50 $\pm$ 18.41	87.33 $\pm$ 28.57	0.046	0.688	
BPI score	Mean $\pm$ SD	4.40 $\pm$ 2.52	4.50 $\pm$ 2.28	4.97 $\pm$ 2.36	3.00 $\pm$ 2.71	5.00 $\pm$ 1.73	-0.013	0.906	
Duration of pain in days	Mean $\pm$ SD	26.70 $\pm$ 24.65	10.00 $\pm$ 5.10	27.29 $\pm$ 25.33	8.50 $\pm$ 0.58	45.33 $\pm$ 30.67	-0.001	0.990	
Degree of spasticity	Mean $\pm$ SD	2.05 $\pm$ 1.39	1.00 $\pm$ 1.41	2.13 $\pm$ 1.38	0.75 $\pm$ 0.96	2.33 $\pm$ 0.58	-0.071	0.534	
Muscle power	Mean $\pm$ SD	2.62 $\pm$ 1.36	2.20 $\pm$ 1.64	2.10 $\pm$ 1.19	3.00 $\pm$ 0.82	1.67 $\pm$ 1.16	-0.132	0.242	

Ultrasonographic grades of the painful affected hemiplegic shoulder were positively correlated with age ( $P = 0.955$ ), and the stroke duration ( $P = 0.688$ ), while negatively correlated with the BPI score ( $P = 0.906$ ), shoulder pain duration ( $P = 0.990$ ), degree of spasticity ( $P = 0.534$ ), and muscle power ( $P = 0.242$ ). All correlations were not significant. Ultrasonographic grades of the unaffected shoulder were significantly correlated with the stroke duration ( $P < 0.001$ ), the BPI score ( $P < 0.05$ ), shoulder pain duration ( $P < 0.001$ ),

and degree of spasticity ( $P < 0.001$ ), while not significantly correlated with the muscle power ( $P = 0.893$ ), [Tables 5 and 6](#) and [Fig. 1](#).

### 3.1. Cases

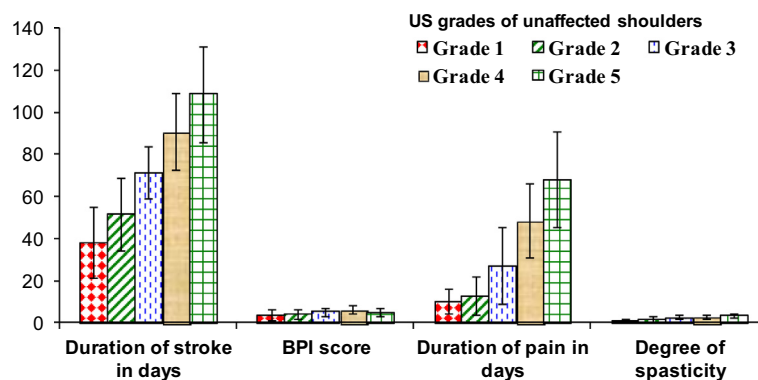
[Figs. 2–6](#) represent the abnormal ultrasound grades seen in the painful hemiplegic shoulder.



**Table 6** Correlation between clinical variables and U/S grades of unaffected shoulders.

Clinical variable		U/S grades of unaffected shoulder					Spearman's rho	
		Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	<i>r</i>	<i>P</i> -value
Age in years	Mean $\pm$ SD	62.60 $\pm$ 9.21	60.17 $\pm$ 8.81	61.50 $\pm$ 12.84	63.69 $\pm$ 7.12	64.33 $\pm$ 5.85	0.023	0.841
Duration of stroke in days	Mean $\pm$ SD	38.37 $\pm$ 16.96	51.56 $\pm$ 17.34	71.50 $\pm$ 12.33	90.77 $\pm$ 18.24	108.78 $\pm$ 22.75	0.812	0.000*
BPI score	Mean $\pm$ SD	3.87 $\pm$ 2.49	4.28 $\pm$ 2.37	5.30 $\pm$ 1.89	6.54 $\pm$ 1.85	5.00 $\pm$ 2.18	0.340	0.002*
Duration of pain in days	Mean $\pm$ SD	10.10 $\pm$ 5.87	12.89 $\pm$ 8.82	27.10 $\pm$ 18.41	48.77 $\pm$ 17.75	68.22 $\pm$ 22.82	0.747	0.000*
Degree of spasticity	Mean $\pm$ SD	1.00 $\pm$ 1.11	1.78 $\pm$ 1.12	2.50 $\pm$ 0.97	3.00 $\pm$ 0.91	3.44 $\pm$ 1.13	0.647	0.000*
Muscle power	Mean $\pm$ SD	2.40 $\pm$ 1.43	2.44 $\pm$ 1.38	1.90 $\pm$ 0.74	2.46 $\pm$ 1.13	2.56 $\pm$ 1.51	-0.015	0.893

BPI; Brief Pain Inventory.

\* Significant ( $P < 0.05$ ).

**Fig. 1** Correlation between some clinical variables and U/S grades of unaffected shoulders.

#### 4. Discussion

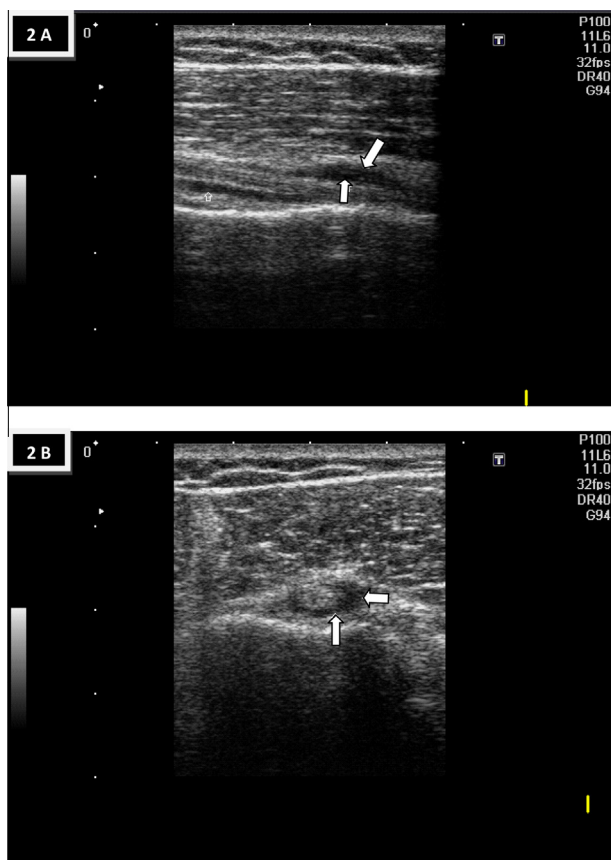
The PHS is a common complication after stroke and has a significant impact on patient rehabilitation and can decrease the functional performance of activities of daily living. The PHS usually appears within the first few weeks after a stroke and more frequently associated with a spastic than a flaccid stage. Following stroke, all the protective mechanisms of the normal shoulder girdle muscles are destroyed. The gravitational pull on the unsupported upper limbs may cause traction injuries to the peri-articular soft tissues and nerves. Furthermore, repeated inappropriate stretching and passive ROM exercises often result in injury to the rotator cuff (29).

Despite numerous theories and studies, the mechanisms underlying a painful shoulder in hemiplegic patients are still poorly understood. Therefore, it is important for the clinician to identify the precise cause of hemiplegic shoulder pain to obtain a good treatment outcome (11). Brunnstrom (17) developed a test in which movement patterns are evaluated and motor function is rated according to the stages of motor recovery. However, in patients with PHS, the shoulder abnormalities cannot be described according to the motor recovery stages alone. Furthermore, the RS2, which represents prominent spasticity, clinicians usually complain of a greater difficulty in performing physical examinations as compared with the other stages (11). The estimation of the cause of shoulder pain in this stage based only on physical examination is usually impossible and is occasionally confusing for clinicians. Therefore, the use of imaging techniques is necessary and the use of

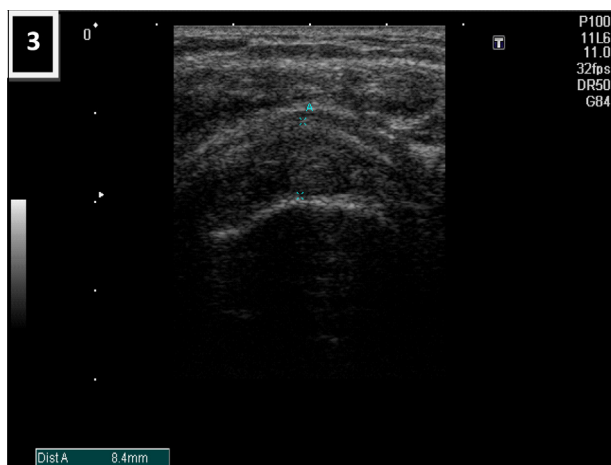
less complicated and non invasive methods is required in these patients (12). Ultrasonography is a useful diagnostic tool for the assessment of rotator cuff and non-rotator cuff disorders of the shoulder. It is a non invasive and inexpensive imaging modality that does not expose patients to radiation, and this method allows for the evaluation of structural status of the tissue, as well as the examination of dynamic movement of the affected area. Thus, ultrasonography is an imaging technique which allows for both anatomical and functional assessments of the shoulder in post-stroke hemiplegic patients (11).

In the present study, the age of the studied patients ranged from 35 to 75 years (mean  $62.29 \pm 8.93$  years). Moreover, our results showed that variable sonographic findings were seen in patients with PHS in which the most frequent U/S grade in both the affected (46.25%), and unaffected (37.50%) shoulders was U/S grade I with no significant correlation ( $P = 0.658$ ) found in the U/S grades between the affected and unaffected shoulders. According to our study, the clinicians were able to manage adequately the shoulder pain of patients according to the sonographic findings. Additionally, our results revealed non-significant ( $P = 0.114$ ) relation between the U/S grades and the Brunnstrom motor recovery stages of patients with PHS. This is in agreement with Lee et al. (12) who stated that there was no significant correlation with the sonography grades and the motor recovery stages.

After hemiplegic stroke, abnormal neuromuscular features induce compensatory adaptations, which may influence the structures and functions of unaffected and affected extremities in hemiplegics. In this study, we hypothesized that hemiplegic



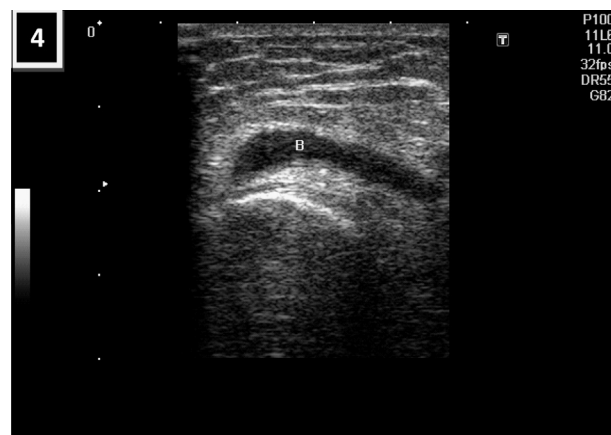
**Fig. 2** (A & B): longitudinal (A) and transverse (B) ultrasound scans of the biceps tendon sheath show anechoic fluid of effusion surrounding the long head of biceps tendon (arrows) (grade 1).



**Fig. 3** Longitudinal ultrasound scan of the supraspinatus tendon demonstrates heterogeneous echogenicity of swollen tendon with increased tendon thickness (8.4 mm) (grade 2).

stroke affects not only the shoulder affected by the hemiplegia, but also the unaffected shoulder (11).

In the current study, we found that the abnormal U/S findings are more frequent in the painful hemiplegic shoulders (65/80; 81.25%) than the contralateral unaffected shoulders (38/80; 47.5%), where the biceps tendon sheath effusion (grade 1



**Fig. 4** Longitudinal ultrasound scan reveals small amount of fluid collection in subacromial-subdeltoid bursa (bursitis) (grade 3).



**Fig. 5** Longitudinal ultrasound scan of the supraspinatus tendon reveals focal hypoechoic defect at the articular surface of the tendon, not reaching the other side (the arrow), that is consistent with partial-thickness tear (grade 4).



**Fig. 6** Transverse ultrasound scan of the supraspinatus tendon demonstrates a hypoechoic defect of full-thickness tear (grade 5) with the absence of the tendon (arrows) at the greater tubercle of the humeral head.

U/S) (51.25%) and the SA–SD bursitis (grade 3 U/S) (43.75%) were the most frequent abnormalities in the affected painful shoulder. Moreover, we observed that grade 3 of abnormal sonographic findings was more frequent in patients of RS3 (46.15%) and RS1 (42.86%) groups. On the other hand, the most frequent abnormal sonographic finding among patients with RS2 was grade 1 U/S rating score as more than half of patients with RS2 (62.5%) had biceps tendon effusion by U/S examination. This is in accordance with results obtained by Cho et al. (11).

There is an increased glenohumeral friction in the hemiplegic shoulder. Therefore, the stretch force caused by abnormal scapula-humeral rhythm to the flaccid shoulder, can cause substantial muscle and tendon injury in the rotator cuff (30). Additionally, in patients with increasing spasticity, high-grade sonographic findings, such as a rotator cuff tear or bursitis, were expected. However, although rotator cuff tears may be expected in some stroke patients, some investigators have suggested that these tears do not occur more commonly in stroke survivors than in an age-matched healthy population (31).

Our results showed that, grade 3 (SA–SD bursitis) of abnormal sonographic findings was more frequent in patients of RS3 (46.15%) and RS1 (42.86%) groups. On the other hand, the most frequent abnormal sonographic finding among patients with RS2 was grade 1 U/S (biceps tendon effusion). This is in agreement with the results obtained by Huang et al. (32) who stated that the main abnormalities in hemiplegic shoulders were effusion of the biceps tendon and SA–SD bursitis which were significantly more than in non-hemiplegic shoulders with subsequent limitation in the range of motion of shoulder joints. Furthermore, as in previous studies (31,32), our results depicted that full thickness rotator cuff tear (grade 5 U/S) was only present in 3.75% ( $n = 3/80$ ) of our patients. This is in agreement with the study obtained by Lee et al. (12) who found full thickness rotator cuff tears in only 3% of patients.

In the study obtained by Pong et al. (29) they stated that, the rating scores of the affected shoulders were positively correlated with the patient age. They suggested that elderly individual rotator cuff tendons may be more prone to injury than those of younger individuals, as a result of progressive degeneration in aged tendons occurring prior to stroke. On the other hand, they stated that, the unaffected shoulder was not statistically significantly correlated with age. So, they assumed that the patient group did not have any premorbid shoulder injuries, and that patients are more prone to post-morbid rotator cuff injuries with increasing age due to greater magnitudes of weaknesses caused by stroke. Furthermore, they concluded that, the determination of the muscle tone in the upper extremities following stroke may have a protective role against injury of rotator cuff tendons.

This is in agreement with our results, as we found that the U/S grades of the affected PHS were positively correlated with age ( $P = 0.955$ ), and the stroke duration ( $P = 0.688$ ), while negatively correlated with the BPI score ( $P = 0.906$ ), shoulder pain duration ( $P = 0.990$ ), degree of spasticity ( $P = 0.534$ ), and muscle power ( $P = 0.242$ ). However, all these correlations were not significant. In contrary, ultrasonographic grades of the unaffected shoulder were significantly correlated with the stroke duration ( $P < 0.001$ ), the BPI score ( $P < 0.05$ ), shoulder pain duration ( $P < 0.001$ ), and degree of spasticity ( $P < 0.001$ ), while not significantly correlated with the age ( $P = 0.841$ ) and muscle power ( $P = 0.893$ ).

Regrettably, despite the usefulness of sonography, we met some limitations. First, we did not perform reference standard techniques such as shoulder MRI, MR arthrography, arthroscopy, or open surgery for diagnostic confirmation. However, MR examinations of patients with PHS were actually impossible to perform as a result of limitations of positioning and involuntary movements of the affected upper limbs. Second, the duration of this study was short and a relatively small number of patients enrolled in our study. So, longer term follow-up of a larger number of hemiplegic patients will be needed. In our study, despite such limitations in the dynamic sonography examinations, we could visualize the rotator cuff including the biceps tendon and SA–SD bursa in all patients.

In summary, hemiplegic stroke results in injury not only to the affected shoulder, but also to the shoulder on the unaffected side. We found that, there was no correlation between the stages of motor recovery and the grades of sonographic findings in patients with painful hemiplegic shoulder. Therefore, we could not estimate the pathology of the shoulder joint according to the motor recovery stage. Shoulder sonography is an essential method in evaluation of soft tissue changes of the shoulder girdle and may be helpful to determine effective treatment methods for stroke patients with hemiplegic shoulder pain. Furthermore, it might be a useful imaging technique in the assessment of both rotator cuff and non-rotator cuff disorders. Also, it provides dynamic capabilities to examine patients in multiple scanning planes and with specific arm positions or movements in addition to having the ability to focus the examination on the precise region of maximum discomfort. So, the proper management of spasticity through adequate U/S imaging of both the affected and unaffected shoulders of patients with PHS combined with minimal anti-spastic measures with avoidance of overuse of the unaffected shoulder will be helpful for patients in the prevention of shoulder injuries following hemiplegic stroke.

## Conflict of interest

None.

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